DOCUMENT RESUME

ED 123 036 SE 019 521

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TITLE	Analytic Networks and Task Domains for a Primary Grade Science Curriculum.
INSTITUTION	Southwest Regional Laboratory for Educational Research and Development, Los Alamitos, Calif.
REPORT NO	SWRL-TN-2-72-51
PUB DATE	1 Nov 72
NOTE	31p.
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage
DESCRIPTORS	*Curriculum; *Curriculum Development; Elementary School Science; Evaluation; Instruction; Objectives; *Primary Education; *Process Education; Science Education; Skill Development
IDENTIFIERS	Southwest Regional Laboratory

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SWRL

SOUTHWEST REGIONAL LABORATORY
TECHNICAL NOTE

DATE: November 1, 1972

NO: TN-2-72-51

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In the design of instruction, specification of desired learning outcomes can be viewed as having two interrelated aspects: structural and operational. The structural aspect refers to relevant subject matter content and its logical structure, while the operational aspect refers to what the learner does with that content. This paper discusses the relation between these two aspects, describes various levels of analysis for each aspect, and finally presents structural and operational specifications for a science component of a primary grade curriculum. These specifications define a domain within which detailed skills analyses and empirical investigations of instructional problems can be carried out. A central assumption underlying the current analysis is that appropriate coordination of the structural and operational aspects of learning outcomes can result in the development of skills with considerable generality and transfer potential.

STRUCTURAL AND OPERATIONAL ASPECTS OF INSTRUCTIONAL OUTCOMES

In a previous paper (Smith, 1972) three levels of analysis were proposed for describing the structural aspect of instructional outcomes. At the *systemic* level, specialized concepts of discipline or subdiscipline are specified (e.g., weight, cost, mammal, and electron). The *analytic* level represents an abstraction of the logical structure of the systemic content. Each systemic concept is an example of some analytic concept (e.g., "weight" is an example of a "variable name," while "mammal" is an example of a "class name"). Finally, the *particular* content involves the specific materials, events and so on which are used to exemplify the systemic content (e.g., "mammal" might be exemplified by pictures of lions, horses, elephants, and people).

Specification of content at these three levels does not, by itself, define the operational aspect of an instructional component, that is, what the learner should be able to *do* with that content. However, the structure of content as reflected by networks or related analytic concepts has definite implications for operations appropriate to the content.

For example, the variable-value analytic network includes the following components:

elements -	The phenomena to be described, compared, related or otherwise studied (e.g., objects, events, systems, and sets).
variable name -	The name of an aspect or dimension on which elements may differ (e.g., color, weight, and cost).
values -	The terms, numerals or other symbols available for assignment to elements for a variable (e.g., red, four pounds fifty cents).
observation/measurement - procedure	The standard procedures or algorithms used to assign values of a variable to particular elements (e.g., use of a centigrade thermometer for determining temperatures).

Conceptual systems examplifying the structure represented by the variable-value network are amenable to operational requirements which reflect that structure. The kinds of information which serve as input and output for a given operational requirement can be classified in terms of analytic concepts. A description of an operational requirement with the input/output relations defined in terms of analytic concepts is called a task description. For example, one task can be described as follows: *carry out an observation/measurement procedure to determine which value of a named variable accurately describes a given element*. The input for the task is an *element* and a *variable name*. The output is an *observation/measurement procedure* and a *value*.

By selecting systemic and particular content, and by specifying the instructions, an *item* exemplifying a given task may be constructed. For example, one item can be formed by selecting weight as the variable and a particular sea shell as the element, and by specifying the instruction as, "Determine the weight of this object." Although access to any needed equipment would have to be made available, no direction to that equipment would be given since the task does not specify the observation/measurement procedure as input. It must be provided by the individual performing the task. Clearly the task represents a large number of items differing as to the variable name, the object, and the instruction as well as the details of the general context. At the analytic level, however, these items share a common structure.

Beyond their use in describing existing items, the components of an analytic network define the kinds of information or actions which can potentially serve as input and output in items. Thus, any two subsets of components of a network are suggestive of a potentially important task. The definitions of the components can be used to interpret input-output combinations as tasks which are meaningful for that network. For example the input-output combination

input: variable name
output: value

is meaningfully interpreted as supplying values conventionally associated with the given variable name. Once a task has been defined for an analytic network, it identifies an operational requirement appropriate to any conceptual system exemplifying that analytic network. The task than provides the basis for generating items.

The specification of a task does not indicate the information processing strategies, perceptual-motor performances, or other skill components by which items exemplifying that task might be carried out. However, the probability of payoff from detailed behavioral analyses is greatly increased by prior selection of important tasks constructed from analytic networks which span large domains of systemic and particular content. If a large number of systemic examples of the analytic concepts exist, then tasks described in terms of those concepts necessarily have an equally large number of potential applications. If behavioral analysis of possible modes of performance in several applications of a task reveals similar skill components, the generality and relevance of the skills selected for training will be assured.

From the point-of-view described above, the initial specification of the structural and operational aspects of the outcomes for an instructional component should be in terms of analytic networks and associated task domains, respectively. These initial specifications may be revised in light of the results of subsequent behavioral analysis and empirical studies of learning and performance on items for specific tasks. However, such specifications define a restricted domain within which further detailed analyses may be carried out.

ANALYTIC NETWORKS FOR USE IN INSTRUCTIONAL DESIGN FOR SCIENCE INQUIRY OUTCOMES IN A PRIMARY GRADE CURRICULUM

Several analytic networks have been identified which characterize the structure of much science content in existing primary science programs (Smith, 1972). Three analytic networks were selected as a basis for instructional design work: the variable-value network, the class-member network, and the intra-element relation network.

As defined above, the variable-value network is built on the idea of primitive entities or *elements*. When these entities are described, compared or otherwise studied, only certain aspects of them are considered. These aspects are characterized in terms of *values* for dimensions or *variables*. Each variable is associated with one or more observation/measurement procedures.

The class member network is built upon the variable-value network. This relationship is reflected in the following definitions for the analytic concepts comprising the class-member network.

class -	A designated set of elements (e.g., the set of zebras).
class member -	An element which is in a class (e.g., a particular zebra).

class rule -	A decision rule by which it may be determined whether or not an element is a member of a class, consisting of values and logical connectives (e.g., an animal which has four legs, black and white stripes, etc.)
class name -	Name applied to an element as a consequence of its membership in a specific class (e.g., "zebra").
defining value - (for a class)	A value employed in a class rule (e.g., four legged).
relevant variable - (for a class or set of classes)	A variable whose values are employed in the rule for a class or in the rules for a set of classes (e.g., number of legs).
partition -	A set of mutually exclusive (pairwise disjoint) classes constituting a superordinate class (e.g., the set of animal species).
partition name -	A term or phrase referring to a specific partition, that is, to a specific set of mutually exclusive subclasses of a specific superordinate class (e.g., "species of animal").

Although some classes may be adequately dealt with in isolation, most seem to require the context of a system of related classes. For this reason, the last two analytic concepts were included from the outset.

The third analytic network selected was the intra-element relations network. Intra-element relational rules specify a relation between an element's membership in one class and its membership in another class defined in terms of different relevant variables.[1] Thus, these rules

[1]Simple taxonomic heirarchies which simply add further defining values to the class rules are not included here. Such relations can be derived directly from the class rules. This is not the case for intra-element relations.

relate one set of characteristics of an element (those specified by the rule for one class) to another set of characteristics for the same element (those specified by the rule for the second class).[2] For example, the relational rule "clay soils have a large water holding capacity," relates the defining values of clay soils (i.e., their particle size and chemical composition) to a value (large) for a different variable (water holding capacity). Typically, many intra-element relations are expressed in terms of the classes of important partitions of the element studied in a given discipline. Agronomists use many relations, such as the above example, involving the composition partition and the water holding capacity partition of soils.

In addition to the components of the class-member network, the following are components of the intra-element relations network:

intra-element relation -	A relation between membership in one class and membership in another class, i.e., between the corresponding sets of defining values (e.g., class inclusion).
intra-element relational rule -	A rule specifying an intra-element relation between two classes (e.g., "clay soils have a large water holding capacity").
related classes -	An ordered pair of classes defined by different relevant variables, and between which an intra-element relation holds (e.g., clay soils and soils with high water holding capacity).

[2]In the limiting case, the rule merely relates a value of a single variable to a value of another variable for a set of elements. When a value of a single variable occurs in an intra-element relational rule, it will be treated as a class rule with a single defining value.

related partitions - Two partitions of a superordinate class ~~which are~~ defined on different relevant variables, such that at least one class of one partition is related to at least one class of the other (e.g., the soil composition partition and the soil water capacity partition).

There were several reasons for selecting these networks. The first was the scope of their applications. Each was found to reflect the structure of a considerable portion of the systemic and particular content of extant orimary science programs (Smith & McClain, 1972; McClain, 1972). Further support for their generality is provided by the attention given to analytic concepts from these networks by philosophers of science.

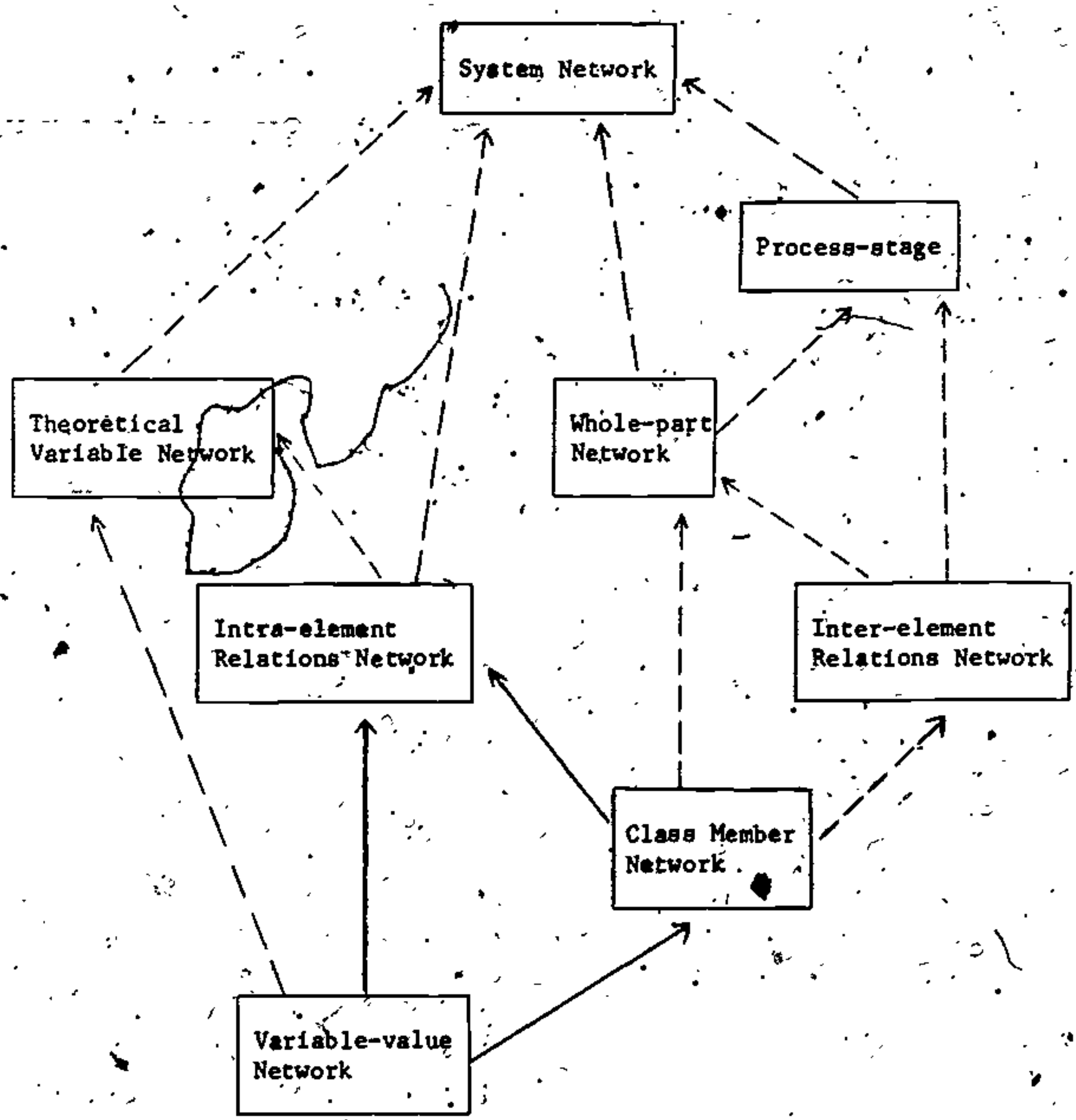
Second, these three networks are interrelated in a fundamental way. The variable-value network provides a foundation for the class-member network while both of these underlie the relational network (see Figure 1). Although it might not be necessary to carry the analyses through to the relational level for the primary curriculum, it is that level at which the power and utility of the variable-value and class-member networks are revealed. An analysis of the variable-value or class-member networks in isolation might fail to provide an adequate basis for the relational network. Further, it is quite likely that instruction which reaches the relational level rather quickly will prove more highly motivating than that which deals extensively with the lower level networks in isolation. The interdependence also means that considerable practice with the lower level networks will be obtained in the context of use of the higher level ones. This should promote consolidation and retention of earlier learning.

A third reason for these selections is the foundation they provide for other networks. Some of the networks which might be built upon this foundation are also indicated in Figure 1. The class-member network is a basis for inter-element relations, those in which a member of one class is related in a specified way to a different element in another class (e.g., hydra prey upon daphnea). A specialized intra-element relation, the whole-part relation, is broadly applied in the biological sciences and forms the basis of a network involving the function of the part in relation to the activity of the whole. This network would probably provide a point of departure for a systems network. The variable-value, class-member and part-whole networks lead into the process-stage network.

The variable-value network, based on empirical variables, and the intra-element relations network provides a foundation for a theoretical variable network to cover variables defined only in terms of other variables (e.g., energy). With the addition of the theoretical variable network, the power of the systems network would be considerably increased.

SCIENCE TASK DOMAINS

The analytic networks described above represent criteria for the structural aspect of science outcomes for the primary curriculum. That is, they prescribe the kinds of concepts and conceptual systems with which children will learn to function. As discussed above, the



Key: ——→ relations already analyzed
----→ anticipated relations

Figure 1. Interrelations among analytic networks.

selection of analytic networks puts constraints on and is suggestive of the operational aspect of the outcomes. Specifications of the operational aspect take the form of tasks defined for each analytic network.

Several methods were employed in obtaining tasks for the selected analytic networks. One method was the review and analysis of relevant literature and materials. One source was extant instructional programs which involve systemic content exemplifying the analytic networks (McClain & Smith, 1970). Another source was psychological and educational literature related to the kinds of concepts included in the network (Bruner et al., 1956; Inhelder & Piaget, 1964). The performance requirements from these sources were described in terms of the analytic networks to produce potentially useful tasks.

A second method made systematic use of the components of the network in generating new tasks. Since the components represent information or action which can serve as input or output, any two subsets of components represent the basis of a potentially useful task. Not all such combinations result in meaningful tasks, however. Judgement is required in applying the defined relations among the components of the network in the interpretation of combinations as tasks.

By taking all possible combinations of components, many tasks can be generated and a degree of completeness can be assured. Such a comprehensive analysis establishes a domain of alternatives for the operational aspect of instructional outcomes and thus defines the decisions that must be made. A domain of alternatives also allows a determination of the representativeness of any given subset of tasks. Selection of a representative sample of tasks increases the probability of identifying generalizable strategies and other skills.

In addition to the judgement involved in interpreting the combinations of components as tasks, decisions are required in selecting from among the large number of tasks generated. Skill analysis will provide the basis for many such decisions. However, some initial selection of tasks which will define terminal outcomes for an instructional component is required. Ideally, these selections would be made on the basis of analyses of the requirements likely to be made of the child in later instruction, and in his everyday life in both the immediate and distant future. Such analyses are not currently available, however, and may not even be possible at the present time. Thus, the selections represented by the tasks specified below represent professional judgement. It should be recalled that these selections were not made in isolation, however. They were made after the careful selection of analytic networks which appear to have broad generality, and against the background of relatively comprehensive domains of tasks for each network.

The exercise of professional judgement in the selection of tasks involved the application of the following criteria:

1) Does it represent acceptable scientific inquiry?

2) Does it have informative value for the performer?

3) Is it relevant to higher level networks?

4) Is it amenable to strategies useful to primary school children?

5) Is it amenable to strategies applicable to the tasks selected from the other networks?

First priority was given to tasks which appeared to meet both the relevance and the hierarchical criteria. Second priority was given to tasks which met only the hierarchical criteria. Tasks which met only the relevance criteria were selected only when a network was not adequately represented otherwise.

TASK DOMAIN FOR THE VARIABLE-VALUE NETWORK

The task domain for the variable-value network is divided into four subclasses: simple description, qualitative comparison, seriation, and sorting tasks. Only the components of the variable-value network may serve as input and output. Although items for these tasks may involve more than one variable (e.g., a description on several variables), no class rules are involved.

Simple Description Tasks

Simple description tasks involve elements, values and observation/measurement procedures. They may involve variable names. These tasks deal with element-value relations, but not with element-element or value-value relations.

Three simple description tasks were selected for specifying science outcomes for the primary curriculum (see Table 1). The nondirected task represents a relatively high level of independent inquiry. It also requires the recall and selection of variables, an important skill

TABLE 1

SIMPLE DESCRIPTION TASKS

Task Name	Given Input	Required Output	Sample Item
Element Identification	a set of elements a value for a variable	an observation/measurement procedure for the variable an element described by the given value	Given samples of salt, sugar, flour, sand, and chalk. "Determine which substance is soluble in water?"
Directed Description	an element a variable name	an observation/measurement procedure for the named variable a value for the named variable which describes the given element	Given a mineral specimen. "Determine and report the hardness of this rock."
Nondirected Description	an element	an observation/measurement procedure for a variable a value describing the given element on that variable (multiple cycles may be required)	Given a leaf specimen. "Describe this leaf as completely as you can."

component in many higher level tasks. The directed description task requires a response to a variable name as do many higher level tasks. The element identification task frequently occurs in a variety of classroom situations, and involves skill components common to many higher level tasks, namely value decoding and some type of search strategy.

Comparison Tasks

Comparison tasks involve relations between two or more elements with respect to a specific variable. The values assigned to elements as a result of comparisons refer to the relation between that element and a specific set of other elements. These relations may be qualitative (specifying only same-different judgements), or quantitative (specifying an amount). Quantitative relations can be further subdivided into ordinal, interval and ratio relations. Only qualitative and ordinal quantitative relations will be considered further at this time. For simplicity, values referring to qualitative relations will be called *comparative values* (e.g., same, different). Those referring to ordinal relations will be called *ordinal values* (e.g., hotter, more dense, first, third). It should be noted that the applicability of comparative or ordinal values to an element is dependent, by definition, on the set of elements with which that element is compared. Comparison tasks therefore involve the specification of a set of elements as a given input or required output.

Two classes of comparison tasks have been defined, corresponding to the two types of values: comparative tasks and seriation tasks. The *comparative tasks* selected for the primary curriculum are listed in Table 2. The non-directed comparison task represents a relatively high level of independent inquiry. It also appears to be satisfactory vehicle for building skills required for sorting tasks. The subset formation task was selected, somewhat arbitrarily, for its contribution of skills. While the non-directed comparison task involves recognition and description of relations between a given set of elements, the subset selection task requires the formation of a subset of elements meeting specified comparative criteria. The directed comparison task is included here because it provides a vehicle for skills required for response to variable names. These skills are required in many higher level tasks where variable names serve as input or mediating responses.

The selected seriation tasks are listed in Table 3. The non-directed seriation task was selected because of the relatively high level of independent inquiry it represents and because it appears to incorporate skills important in the discovery of relations between variables. Another seriation task also appears to incorporate skills important to such discoveries, namely, the seriation variable identification task. The directed seriation task was included as a vehicle for the skills required in responding to variable names.

Sorting Tasks

Sorting tasks involve subsets of elements formed on the bases of similarity on a specific variable. The sorting tasks selected are

TABLE 2

COMPARATIVE TASKS

Task Name	Given Input	Required Output	Sample Item
Comparison Variable Identification	a set of elements a comparative value	the name of a variable for which the given comparative value characterizes the relation between the given elements (multiple cycles mav be required)	Given a bean plant, a corn plant and a cactus. "In what ways are these plants the same?" (e.g., color, means of attachment)
Directed Comparison	a set of elements a variable name	the comparative value charcterizing the relation between the given elements on the named variable	Given a bean leaf and a corn leaf "Compare the shapes of these leaves." (e.g., different)
Nondirected Comparison	a set of elements	a variable name the comparative value characterizing the relation between the given elements on the named variable (multiple cvcles may be required)	Given a mouse, a frog, and a lizard "Compare these animals." (e.g., same number of legs, different body covering)
Subset Formation	a set of elements a variable name a comparative value	a subset of elements such that the relation between them on the named variable is characterized by the given comparative value	Given specimens of teeth from a cow, a man, a dog, and a rat. "Pick out some teeth which have the same shape." (e.g., the double molars)

TABLE 3

SERIATION TASKS

Task Name	Given Input	Required Output*	Sample Item
Seriation Variable Identification	a set of elements ordered such that their order corresponds to their order on a variable	the name of the variable on which the elements are ordered	Given a set of plants ordered by height. "Why were these plants placed in this order?"
Directed Seriation	a set of elements a variable name	the set of elements ordered on the named variable	Given a set of mineral samples. "Place these samples in order according to their hardness."
Nondirected Seriation	a set of elements	the set of elements ordered on a variable	Given a set of corn seedlings. "Show a way that these seedlings differ by placing them in order."

* An observation/measurement procedure is required output for each task.

listed in Table 4. These selections parallel those for the seriation tasks. The non-directed sorting task stands on its own as an inquiry task while both the non-directed sorting and the sorting variable identification tasks provide vehicles for skills useful in discovering relations among variables. The directed sorting task is included to assure that sorting on a specific variable can be brought about through the use of the variable name.

THE TASK DOMAIN FOR THE CLASS-MEMBER NETWORK

Tasks for the class-member network involve class rules by which the applicability of a class name to an element may be determined. Several classes of tasks have been distinguished. Element classification requires some identification of class membership for a given element or elements. Member specification tasks provide information identifying a class, but require specification of elements which are members. Both of these task classes presuppose that a class rule is known by or presented to the individual performing the task. The third task class involves inferring a class rule. Elements, or description of them, and information as to whether or not they are members are provided as input, while a class rule accounting for the membership information is required as output.

Tasks from each of the above classes were selected (see Table 5). Three element classification tasks were selected. The non-directed classification task stands by itself as relatively independent inquiry while directed classification and partition identification provide

TABLE 4

SORTING TASKS

Task Name	Given Input	Required Output*	Sample Items
Nondirected Sorting	a set of elements	the set sorted into subsets on a specific variable	Given samples of liquids differing in color, viscosity and opacity. "Sort these substances into groups on one variable."
Sorting Variable Identification	a set of elements sorted into subsets on a specific variable	the name of the variable on which the elements are sorted	Given drawings of irregular polygons differing in area and number of sides, sorted by number of sides. "How have these figures been sorted?"
Directed Sorting	a set of elements a variable name	the set sorted into subsets on the named variable	Given a set of small common objects and access (but not direction) to a container and water. "Sort these objects by their buoyancy."

*An observation/measurement procedure is required output for each task.

TABLE 5

CLASSIFICATION TASKS

Task Name	Given Input	Required Output	Sample Items
ELEMENT CLASSIFICATION			
Nondirected Classification	a set of elements	subsets of elements by classes of a partition class name for each subset	Given pictures of mountains, deserts, valleys, etc. "Classify these pictures by placing them in groups. Give a name for each class."
Directed Classification	an element a partition name	the name of the class of the name partition of which the element is a member	Given a picture of a rocky inter-tidal zone area at low tide. "Name the class of habitat shown in the picture."
MEMBER SPECIFICATION			
Member Selection	a set of elements	the element(s) which is (are) a member of the named class	Given pictures of rain, sleet, snow, and fog. "Which picture shows sleet?"
Rule Application	a set of elements a class rule a class name	the element(s) which is a member of the named class	Given pictures of cirrus, stratus, and cumulus clouds. "Cirrus clouds are feathery looking and occur only at high altitudes. Which pictures show cirrus clouds?"

Task Name	Given Input	Required Output	Sample Items
Partition Identification	subsets of elements by the classes of a partition	the name of the partition or class names for each subset	Given subsets of pictures of reptiles, mammals, amphibians and birds. "These animals have been classified by placing them in groups. Tell how they were classified.
Rule Inference	element designated as a member(s) or nonmember(s) of a novel class the class name	a class rule which accounts for the given class membership information	Given samples of igneous, metamorphic and sedimentary rocks. "These (point to igneous rocks) are igneous rocks. These others (point to others) are not. Give a rule for classifying igneous rocks."

vehicles for additional skills. Two member specification tasks were selected. Member selection requires the individual to supply the class rule and represents a frequently occurring classroom task. The rule application task provides a rule. The skills involved in this task relate to comprehension of new verbal information. The rule inference task is a version of the concept acquisition task widely thought to typify informal or contextual learning.

THE TASK DOMAIN FOR THE INTRA-ELEMENT RELATION NETWORK

Tasks selected for the intra-element relations domain represent somewhat arbitrary selection from each of four task classes. Rule application tasks provide a relational rule as input. The selected rule application task (see Table 6) also provides the name of one of the related classes and a set of elements including members and non-members of the named class. The elements must be presented such that membership in the named class cannot be determined by use of the class rule for that class. The required output includes specification of members and non-members of the named class.

Prediction and explanation tasks require a familiar relational rule and class name as output. The selected prediction task provides a partition name as input while the explanation task provides the name of one of the related classes. The forth class of tasks, rule discovery require a novel relational rule as output. The selected rule discovery task provides a set of elements for which a relation holds between

TABLE 6

INTRA-ELEMENT RELATION TASKS

Task Name	Given Input	Required Output	Sample Items
Relational Rule Application	a rule relating membership in two familiar classes the name of one of the related classes a set of elements (presented so that membership in the named class is not directly observable)	specification of those elements which are members of the named class	Given pictures of common wild birds. "Birds with short, pointed bills are usually seed eaters. Which of these birds probably eat seeds?"
Prediction	the name of a partition an element (presented so that its membership in classes of the named partition cannot be directly observed)	the name of the class of the named partition of which the given element is a member	Given a picture of a sea turtle. "In what kind of location would this animal lay its eggs?"
Explanation	a class name an element which is a member of the named class	the name of a related class of which the element is observed to be a member a rule relating membership in the two classes	Given a fish (with observable gills). "How can you tell that this animal lives in water?"

Task Name	Given Input	Required Output	Sample Items
Rule Discovery	a set of elements for which a relation holds between membership in two familiar classes the names of the related partitions	a rule relating membership in the two classes	Given a set of stunted (small) corn plants growing in limited light, and a set of normal (large) corn plants growing in bright light. "What relation can you find between the amount of light and the size of the plants?"

membership in two familiar classes, and the names of the partitions of which the related classes are constituents.

The relational rule application task provides a vehicle for skills involved in comprehending and utilizing rules from secondary sources as in problem solving. The other three tasks represent relatively independent inquiry for primary children while providing a context for development of skills required for higher level inquiry tasks.

DISCUSSION

The relation between task analysis and behavioral analysis of performance requirements for given tasks was mentioned above. As stated by Klahr and Wallace (1970, p. 360), "The objective task structure alone does not yield a valid description of the solution performance, and it is necessary to diagnose the actual psychological processes in great detail to obtain minute descriptions of well supported inferences about the actual sequence and content of the thinking process." However, the resource requirements for such analysis are so great that considerable care must be taken to maximize the probability that generalizable strategies and skills will be identified. Procedures have been described above for structural analyses of content in terms of analytic networks and operational analysis in terms of tasks. These procedures provide a means of defining a greatly restricted domain for behavioral analysis, a domain with considerable potential for the identification of broadly generalizable strategies and skills. Where the time line for program development precludes extensive skills analysis, the procedures provide a means of generating and describing potential outcomes which reflect the logical structure of relevant conceptual systems.

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